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CMG Tech-X metal filaments for metal FFF 3D printing

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Metal filaments & example applications

- ***316L:*** corrosion resistant uses e.g. waterjet turbines, gliders for blinds, jewellery, etc
- ***17-4PH:*** High strength & corrosion resistant uses e.g. crimp jaws, intake adaptors, etc
- ***H13 tool steel:*** High hardness & toughness uses e.g. moulds, dies, cutting tools, etc
- ***100Cr6:*** High hardness & tensile strength uses e.g. pawls, collets, punches, bearings, etc
- ***Copper:*** Thermal & electrical conductivity uses e.g. complex heat sinks, etc
- ***Inconel (IN) 625:*** High temperature uses e.g. crucibles, reactor clips, etc
- ***Inconel (IN) 718:*** High temperature & fatigue strength uses e.g. rings & casings, etc

Typical scaling factors x/y/z % to print green parts

- ***316L:*** 118/118/117 %
- ***17-4PH:*** 119/119/118 %
- ***H13 tool steel:*** 119/119/118 %
- ***100Cr6:*** 119/119/118 %
- ***Copper:*** 119/119/118 %
- ***IN625:*** 119/119/118 %
- ***IN718:*** 119/119/118 %

Range: 116-121% depending on printing parameters, build direction, part size, part geometry and sintering conditions

Printing of CMG Tech-X metal filaments

CMG Tech-X metal filaments are high flexibility metal-polymer composite filaments containing more than 90 percent by weight fine metal powder, allowing printing of parts with high quality surface. Filaments are available in 1.75 mm and 2.85 mm diameters.

120-160 °C print temperature, 20-30 °C bed temperature, bed adhesion materials include blue painter's tape, magnetic PEI sheet & magiggo, 0.6 mm nozzle D most suitable (0.3-0.5 mm nozzle D can also be used). In fact, most parts or a lot of parts can be printed with 0.6 mm nozzle D with decent quality and detail. Additionally, CMG Tech-X metal filaments contain fine metal powders between 0-16 µm, thus good surface quality can be achieved with bigger nozzle diameters and higher z-layer height.

Moreover, printing with bigger nozzle diameters and higher z-layer height lead to higher mechanical properties of part and lower susceptibility of bigger parts to deformation and warping during debinding and sintering. The use of fine metal powder in CMG Tech-X metal filaments allows for a higher surface area per unit volume in the molten state, thus better layer spreading when extruded through a bigger nozzle, leading to better surface and physical attributes of part. Contrary to a smaller nozzle e.g. 0.3 mm nozzle diameter, there is flow restriction through nozzle in the molten state due to the higher surface area per unit volume. As a result, there is lesser effective layer spreading during printing.

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Printers with at least dual gear drive systems (direct drive or Bowden tube) or similar are suitable for printing CMG Tech-X metal filaments with gentle filament loading into drive. In some cases, the dual gear drive should be slightly loosened to reduce pressure on the filament while still driving the filament to prevent filament grinding and for effective feeding.

It is highly recommended to turn on alternate layer direction or clockwise (CW)-counterclockwise (CCW) layer printing mode in the printer software when printing with CMG Tech-X metal filaments. This mode prevents torsion warping during debinding and sintering of printed parts.

Filament treatment

Should the filament get brittle after exposure to the surroundings, it is recommended to warm the spool with filament in an oven at 30-40 °C for about 1-2 hours to bring up the flexibility. Please don't go above 40 °C.

Design considerations for printing green parts

For successful debinding and sintering of printed green parts optimum part design for printing is essential. Some essential part design considerations include:

Part size

Maximum part dimensions for effective debinding & sintering are 100 mm x 100 mm x 100 mm. Larger part dimensions are possible, however, such parts should be printed with infill % between 35-80 % should it be adequate for the application. Parts printed with CMG Tech-X metal filaments can have infill % below 35 % e.g. 5-20 % as the brown part is still very stable after debinding for sintering.

x-y Wall thickness

Usually 2 mm wall thickness is recommended for successful debinding & sintering. However, thicker walls can be used for parts with infill %.

Overhangs

Overhangs should be optimised on part design to use the minimum support structure possible during 3D printing.

Infill %

To reduce filament consumption, save costs and benefit from lightweightness, it is highly recommended to explore the infill % needed to achieve a balance between functionality/performance, lightweight and effective debinding & sintering of part.

Support structures

This can be classified into two categories: (1) support structures for printing only and (2) support structures for printing and sintering.

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For ease of removal of support structures, it is recommended to print with a support z-distance of 0.1 mm. Alternatively, parts can be printed with a lower temperature and support z-distance of 0 mm for easy removal of support structure after printing.

For support structures that are needed for both printing and sintering, it is recommended to gently remove the support structure from part in one-piece with a suitable tool after printing. The green support structure should be debound together with the green part. After debinding a layer of alumina ceramic powder should be applied with a brush on top of the debound support structure. The support structure with alumina ceramic powder layer should then be placed at the position where it was on the part for sintering. After sintering, the support structure should be easily removed with the hand or suitable tool since the alumina ceramic powder layer acts as support release interface after sintering.

Postprocessing of green printed parts

Debinding, sandpapering or similar, sintering and polishing of printed green parts can be carried out at CMG Technologies or with own appropriate postprocessing equipment.

Debinding

In acetone for 24-72 hours with slow ramp to 40-42 °C. Debinding time depends on size, geometry, x-y wall thickness and infill % of part. Weight loss % is typically between 5-6 %.

Part placement on tray in debinding station and tray type are very important. Perforated trays are best for debinding. The part should be placed on tray with the part surface that allows the least surface contact with tray. This allows maximum acetone penetration and circulation in part for optimum debinding. Slight stirring or agitation of acetone in debinding vessel should be carried out to allow uniformity of solvent media. This prevents pressure build-up by removed binder that might cause cracking or warping of part after debinding.

Should a smoother surface be required on the green printed or debound brown part, sandpapering or the so-called wet & dry or similar technique can be carried out on the parts with a sandpaper having a grain size of between 600-1200 or finer. It is easier and quicker to carry out sandpapering on the brown debound parts. Bead blasting can also be carried out on printed green parts to remove burrs.

Sintering

- ***316L:***
  Slow ramp to 1265-1275 °C with dwell for 1-2 hours in H_2 atmosphere with backbone binder removal at 600 °C in overpressure or vacuum. 95 % Ar / 5 % H_2 atmosphere also possible for sintering.

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- ***17-4PH:***
  Slow ramp to 1275-1285 °C with dwell for 1-2 hours in H_2 atmosphere with backbone binder removal at 600 °C in overpressure or vacuum. 95 % Ar / 5 % H_2 atmosphere also possible for sintering.
- ***H13 tool steel:***
  Slow ramp to 1270-1280 °C with dwell for 1-2 hours in N_2 atmosphere with backbone binder removal at 600 °C in overpressure or vacuum
- ***100Cr6:***
  Slow ramp to 1250-1260 °C with dwell for 1-2 hours in N_2 atmosphere with backbone binder removal at 600 °C in overpressure or vacuum
- ***Copper:***
  Slow ramp to 1000-1060 °C with dwell for 1-2 hours in H_2 atmosphere with backbone binder removal at 600 °C in overpressure or vacuum. 95 % Ar / 5 % H_2 atmosphere also possible for sintering.
- ***IN625:***
  Slow ramp to 1280 °C with dwell for 1-2 hours in vacuum with backbone binder removal at 600 °C in vacuum. Clean and pure alumina ceramic plates are needed for sintering due to the very high sensitivity of the alloy to impurities. Presence of impurities in the sintering furnace could impede effective densification of part during sintering or cause overshoot of sintering temperature due to presence of unwanted carbon, leading to melting of metal.
- ***IN718:***
  Slow ramp to 1280 °C with dwell for 1-2 hours in vacuum with backbone binder removal at 600 °C in vacuum. Clean and pure alumina ceramic plates are needed for sintering due to the very high sensitivity of the alloy to impurities. Presence of impurities in the sintering furnace could impede effective densification of part during sintering or cause overshoot of sintering temperature due to presence of unwanted carbon, leading to melting of metal.

  Should a smoother and shinier surface be required after sintering, polishing of sintered parts can be carried out including tumble polishing, magnetic polishing, bead blasting, etc. H13 tool steel and 100Cr6 metal filaments should be polished in oil-based polishing systems to prevent corrosion of parts. Bead blasting can also be carried out on sintered parts for a matte finish.

Typical mechanical & physical properties

All measurements were carried out by external analytical labs. Mechanical property, hardness and density measurements are in accordance with ASTM A370, ASTM E18. and RP146, respectively. All test specimens were printed flat in x-y printing direction.

The mechanical and physical properties such as yield strength (YS), ultimate tensile strength (UTS), elongation at break % (E %), density and hardness are highly dependent on the printing parameters, printer drive system, printer quality and sintering conditions. Below are tables of

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typical mechanical and physical property range for CMG Tech-X metal filaments for as-sintered and heat-treated (HT) metals.

Table 1: Mechanical property range

Metal	YS 0.2% off set (MPa)	UTS (MPa)	E %
316L	160-300	350-550	25-32
17-4PH	800-900	900-920	5.5-6
17-4PH → HT	950-980	980-1000	4.5-5
H13	n/a	600-660	2.5-5.5
H13 → HT	650-700	1000-1100	2.5-5.5
100Cr6	TBC	TBC	TBC
100Cr6 → HT	TBC	TBC	TBC
Copper	34-38	150-154	31-35
IN625	TBC	TBC	TBC
IN718	TBC	TBC	TBC

Table 2: Physical property range

Metal	Density (g/cm³)	Hardness	Electrical Conductivity	Thermal Conductivity
316L	7.2-7.6	55-80 HRB	n/a	n/a
17-4PH	7.5-7.95	35-38 HRC	n/a	n/a
17-4PH → HT	7.5-7.95	39-42 HRC	n/a	n/a
H13	7.42-7.85	536 HV 10 kg	n/a	n/a
H13 → HT	7.42-7.85	613 HV 10 kg	n/a	n/a
100Cr6	TBC	TBC	n/a	n/a
100Cr6 → HT	TBC	TBC	n/a	n/a
Copper	> 8.3	40 HV 1 kg	TBC	TBC
IN625	TBC	TBC	n/a	n/a
IN718	TBC	TBC	n/a	n/a

Any information supplied above are general recommendations and shall be used for informational and guidance purposes only. No information shall be used for other purposes without agreement with customer.